ISSN 2250-3153

A Comparative Study of Groundwater Quality in Shallow and Deep Aquifers in Parts of Active Flood Plain Areas of Ganga and Yamuna Basin

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Abstract- The Indo-gangetic plains in India have got a number of river basins and these river basins by virtue of their hydrological characteristics provide the fluctuation in water quality range within the channel as well as through their aquifer system within the premises of active flood plains. The active flood plains are the dependent factors based on hydro-meteorological characteristics of the respective basins.

In Indo-gangetic plains Ganga and Yamuna river basins plays a pivotal role for the water supply to the urbanized areas as well as agriculture land to their surroundings. The water resources of Ganga and Yamuna river basin are quite similar and maybe defined in terms of three major seasons for the generation of water resource system. These three major seasons are normal monsoon rainfall, snow-melt water and western disturbances.

The study area comprises of parts of Ganga basin as well as parts of Yamuna basin in case of Ganga basin the study area was taken from Rishikesh to Allahabad at Sangam passing through various districts like, Haridwar, Muzaffarnagar, Kanpur, Moradabad, Ghaziabad, Allahabad and Dehradun and in case of Yamuna basin starting from Dehradun, Yamunanagar, Panipat, Sonipat, Faridabad, Karnal and Allahabad.

Since the precipitation affects mostly the physical parameters like pH, electrical conductivity, total dissolved solids and temperature, therefore these parameters were selected for the impact assessment of seasonal fluctuation of precipitation vis-à-vis aquifer system. It was found that the Ganga basin area is affected by snow-melt condition therefore the groundwater quality in shallow aquifer system fluctuates from acidic to alkaline environment in its upper reaches which maybe a useful tool for assessing groundwater quality for the agricultural development, water supply and construction however the Yamuna water quality does not have much impact of snowmelt water, therefore it maintains the groundwater quality at shallow level as moderate and alkaline in reaction. In this way it is found that the difference in water quality of Ganga basin to Yamuna basin, however the Yamuna changes its quality due to urbanization factor in terms of pollution particularly in Delhi areas. It is therefore recommended that the water supply for agricultural, residential and industrial purposes maybe designed according to seasonal fluctuation in these aquifer systems separately for both the river basins. Apart from these many other aspects have been considered which maybe useful for planners, architects, engineers, philosophers working in these areas.

I. Introduction

The Ganga rises in the Garhwal Himalaya (30^o 55'N, 79^o 7'E) as the Bhagirathi. The ice cave of Gaumukh at the snout of the Gangotri glacier, at 3,892 metres above sea level, is recognized as the traditional source of the Ganga. The river cuts through the Himalayas until another head stream, the Alaknanda, joins at Devaprayag. It is below this confluence that the united stream of Bhagirathi and Alaknanda becomes known as the River Ganga.

After running some 250 kilometres from its source, the Ganga pierces through the Himalayas at Sukhi (near Rishikesh), before turning southwestwards for another 30 km where it finally descends into the vast Indo-Gangetic plain at Haridwar (elevation 283m). At this point, the river swells into a mighty stream of 750 metres width. At Allahabad (1020 km from the source), the Ganga is joined on the right by the River Yamuna, which actually contributes more water (57.24 billion cum / annum) than the main river itself, augmenting the flow volume of the Ganga significantly. Rainfall, subsurface flows and snow melt from galciers are the main sources of water in river Ganga.

The river Yamuna, a major tributary of river Ganges, originates from the Yamunotri glacier near Banderpoonch peak (380 59' N 780 27' E) in the Mussourie range of the lower Himalayas at an elevation of about 6387 meters in the district Uttarkashi of Uttarakhand state. Arising from the source, river Yamuna flows through a series of valleys, for about 200 kms, in lower Himalayas and emerges into the Indo-Gangetic plains

Flowing through Poanta Sahib it reaches Hathnikund/Tajewala in the Yamuna Nagar district of Haryana state, where the river water is diverted into Western Yamuna Canal (WYC) and Eastern Yamuna Canal (EYC) for irrigation and drinking purposes.

The river regains water from the ground water accrual and contributions received from feeding canal through Som Nadi (seasonal stream) upstream of Kalanaur before it reaches Delhi. It (in its later stages) receives water from important tributaries like Chambal, Betwa and Ken before joining the river Ganga and the mythical underground Saraswati at Prayag (Allahabad) after traversing a total length of about 1400 Km.

It enters Delhi near Palla village after covering a distance of about 400 Km from its origin and exits from Delhi (NCT) at the village Jaitpur after traversing a distance of 50 km within the NCT. Finally between Delhi and Uttar Pradesh, before the river enters and flows through UP to finally merge with Ganga in Allahabad.

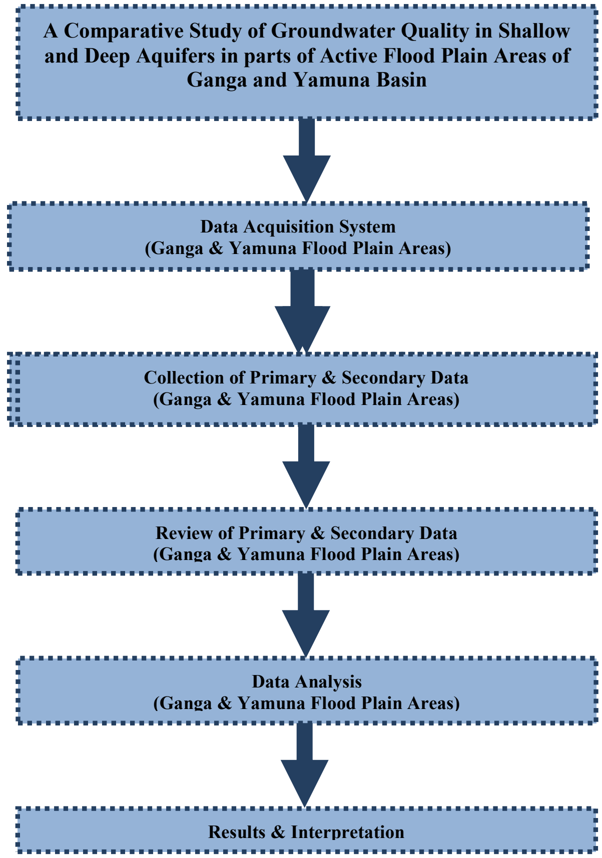
II. OBJECTIVE & SCOPE

The objective of the study was to:

- To delineate the active flood plain areas of Ganga river basin right from Gangotri glacier to the Sangam area at Allahabad with reference to urban settlements
- Delineate the active flood plain areas of Yamuna river basin right from Yamnotri glacier to the Sangam area at Allahabad with reference to urban settlements
- To delineate the deep and shallow aquifers in parts of Ganga river basin in the study area with the help of exploratory deep tubewells strata charts of Central Groundwater Board and shallow farmer tubewells
- To delineate the deep and shallow aquifers in parts of Yamuna river basin in the study area with the help of exploratory deep tubewells strata charts of Central Groundwater Board and shallow farmer tubewells
- To analyze the water quality with the help of specified sampling for deep and shallow aquifers with the help of deep and shallow tubewells in study area for pre-monsoon season
- To analyze the water quality of Gangotri river basin and Yamnotri river basin with special reference to urbanization factor
- To analyze the variation in water quality from the upland areas of Yamnotri and Gangotri to their confluence at Sangam Allahabad
- Finally to establish the relationship of water quality between Yamuna and Ganga river basin and prevention of contamination of groundwater in shallow and deep aquifers by doing the study of groundwater condition and behavior for both the river basin areas and its impact on the shallow and deep aquifers

III. METHODOLOGY

The methodology adopted for accomplishing the above study is illustrated and detailed below.



To delineate the active flood plain areas of Ganga and Yamuna river basin right from origin to Sangam area at Allahabad with reference to urban settlements

In order to delineate the active flood plain areas of Ganga and Yamuna river basin from origin to Sangam at Allahabad the toposheet of Survey of India maps were considered to identify the spot locations of the sampling stations. In this regards secondary sources through published and unpublished literature were also reviewed. The satellite images as well as google maps were also utilized to complete the map.

Apart from these the Ganga and Yamuna active flood plain data published by various organizations like National Institute of Hydrology, Central Water Commission, Central Groundwater Board, Irrigation and Flood Control Departments at district level and state level were also considered. Besides these the Indian Meterological Data was also referred.

To delineate the deep and shallow aquifers in parts of Ganga and Yamuna river basin in the study area with the help of exploratory deep tubewells strata charts of Central Groundwater Board and shallow farmer tubewells

The following district wise hydro-geological reports of Central Groundwater Board were considered in order to delineate the deep and shallow aquifers in parts of Ganga river basin in the study area

Gangotri to Sangam Area

- Groundwater Brochure District Dehradun, Uttarakhand
- Groundwater Brochure of Hardwar District, Uttarakhand
- Groundwater Brochure of Muzaffarnagar, District, Uttar Pradesh
- District Brochure of Kanpur Nagar, District, U.P
- District Brochure of Moradabad, District, U.P
- Groundwater Brochure of Ghaziabad District, Uttar Pradesh
- Groundwater Brochure of Allahabad, District, Uttar Pradesh

Yamnotri to Sangam Area

- Groundwater Brochure District Dehradun, Uttarakhand
- Groundwater Brochure of Yamunanagar, District, Haryana
- Groundwater Brochure of Karnal, District Haryana
- Groundwater Brochure Panipat, District, Haryana
- Groundwater Brochure Sonipat, District, Haryana
- Groundwater Brochure Faridabad, District, Haryana
- Groundwater Brochure of Allahabad, District, Uttar Pradesh

To analyze the water quality with the help of specified sampling for deep and shallow aquifers with the help of deep and shallow tubewells in study area for pre-monsoon season

In order to fulfill the requirement of analysis of water quality with the help of specified sampling for deep and shallow aquifers with the help of deep and shallow tubewells the following methodology was adopted:

For analyzing Yamuna river water quality secondary data were used with the help of published reports of Central Pollution Control Board, National Institute of Hydrology, published research papers as well as proceedings of the seminars and conferences.

For the analysis of groundwater quality of shallow and deep aquifers the published reports of Central Groundwater Board, Central Pollution Control Board, State Groundwater Board, State Pollution Control Board and published research papers as well as proceedings of the seminars and conferences.

Beside this samples were also collected for shallow and deep aquifers through handpumps and tubewells in parts of Ganga river basin area at locations such as Dehradun, Haridwar, Muzaffarnagar, Kanpur, Moradabad, Ghaziabad and Allahabad.

Samples were also collected for shallow and deep aquifers through handpumps and tubewells in parts of Yamuna river basin area at locations such as Dehradun, Yamunanagar, Karnal, Panipat, Sonipat, Faridabad and Allahabad.

IV. RESULTS & INTERPRETATIONS

Delineation of Active Flood Plain Areas of Ganga Basin from Gangotri to Sangam at Allahabad

The Ganga River (about 2525 km long) is fed by runoff from a vast land area bounded by the snow peaks of the Himalaya in the north and the peninsular highlands and the Vindhya Range in the south. The basin encompasses an area of more than a million square kilometers (1,186,000 sq.km) spread over four countries: India, Nepal, Bangladesh and China. With 861,404 sq.km within India itself, the Ganga basin is the largest river basin in India and covers approximately 25 per cent of India‘s total geographical area. The Ganga River flows through the five states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. The extent of the entire Ganga basin is, however, spread over six more states (Delhi, Haryana, Himachal Pradesh, Madhya Pradesh, Chattisgarh and Rajasthan) in addition to the aforementioned five.

The extent of river Ganga within these states is given in Table 1. In the entire basin, Uttar Pradesh and Uttarakhand together share the maximum basin area of 34%, followed by Madhya Pradesh, Bihar and Jharkhand.

Table:1 State-wise Distribution of the Drainage Area of Ganga River in India

S. No.	State	Total Geographical Area (SqKm)	Per Cent of Total Geographical Area
1	Uttar Pradesh & Uttarakhand	294364	34.2
2	Madhya Pradesh	198962	23.1
3	Bihar & Jharkhand	143961	16.7
4	Rajasthan	112490	13.1
5	West Bengal	71485	8.3
6	Haryana	34341	4.0
7	Himachal Pradesh	4317	0.5
8	Delhi	1484	0.2
Ganga Basin (Total)		**861404**	**100.0**

After running some 250 kilometres from its source, the Ganga pierces through the Himalayas at Sukhi (near Rishikesh), before turning southwestwards for another 30 km where it finally descends into the vast Indo-Gangetic plain at Haridwar (elevation 283m). At this point, the river swells into a mighty stream of 750 metres width.

The weather in the Ganga basin is characterized by a distinct wet season during the period of south west monsoon (June to September). The air temperature starts falling with the onset of the monsoon from June onwards, making the weather more humid and equable. The diurnal range between the daily mean minimum and the daily mean maximum temperature reduces progressively as the monsoon advances. Eventually, the lowest diurnal range of temperature occurs at the peak of the monsoon, which is usually in August, though sometimes in July. As soon as the monsoon is over, the diurnal range of temperature starts increasing rapidly to a maximum attained during the month of November.

Rainfall, subsurface flows and snow melt from glaciers are the main sources of water in river Ganga. More than 60 per cent of the water flowing into the Ganga basin comes from the Himalayan streams joining the Ganga from the north. The Peninsular streams combine to contribute only 40 percent of the water, despite the fact that the catchment area of the peninsular streams extends well over 60 percent of the entire Ganga basin

The mountainous section stretches from the river‘s source to Rishikesh. This section has an average bed slope of 1 in 67 and a mean flow rate of 850 cubic metres per second at Rishikesh. The subsequent upper plain section extends from Rishikesh downstream until Allahabad at a slope of 1 in 4,100 and a mean flow rate ranging between 850 and 1,720 cum per second before its confluence with the Yamuna.

Due to their high gradient and a tremendous velocity, Himalayan rivers including the Ganga have a strong erosive power. The geological fact that the Himalayan rivers run through poorly consolidated sedimentary rocks affected by folds and faults results in high rates of erosion and silt deposition. Landslide debris further aggravates the sediment load of river and its deposition and erosion are main cause of flooding in Ganga river basin.

Delineation of Active Flood Plain areas of Yamuna basin from Yamnotri to Sangam at Allahabad

Yamuna is the largest tributary of Ganga river. Starting from Yamnotri it joins river Ganga again at Allahabad where the point of confluence is known as Sangam. The total length of Yamuna from its source at Yamnotri to its confluence with Ganga near Allahabad is about 1376 km, of which about 970 km is in Uttrakhand, 30 kms from the common boundary between Himachal Pradesh and Uttar Pradesh 328 kms from the common boundary between Haryana and Uttar Pradesh and the balance of 48 kms in the Union Territory of Delhi

In the upper reaches of River Yamuna, there are several hill streams join together to form the main stream. There are four main rivers that joins Yamuna in the higher Himalayan ranges, these are Rishi Ganga, which joins on the right bank of Yamuna, where as Unta and Hanuman Ganga joins on left bank. In the lower Himalayan ranges the Yamuna River receives Kamal, Tons, Giri & Bata on its right bank and on left banks receives Aglag & Asan.The Chambal, Betwa, Sindh & Ken are the important tributaries joining Yamuna on right bank in plain & on left bank Hindon river joins River Yamuna. Among all these tributaries, Tons at hills and Chambal at plains are the most important tributaries in terms of their discharges. The Tons is the principal source of water in mountainous range and generally carries more water than mainstream. In plains, during non-monsoon period, River Chambal contributes about 5-10 times more water to the Yamuna than its own flow.

However, since the year 2003, there is a significant reduction in the water quantity that River Chambal discharges into the Yamuna River.

The water flow characteristics of Yamuna River changes significantly from monsoon to non-monsoon seasons. Yamuna river can be divided into four segments from origin to sangam.

The first segment having a length of 157 km starts from Yamnotri and terminates at Hathnikund / Tajewala barrage. The major source of water in this segment is melting of glaciers. The water flow in this segment terminates into Western Yamuna canal (WJC) and Eastern Yamuna Canal (EJC) for irrigation and drinking water purposes in command areas.

The second segment having length of about 224 km lies between Hathnikund / Tajewala barrage and Wazirabad barrage. The main source of water in this segment is ground water accrual. Few small tributaries also contribute water in this segment. The water is diverted in this segment from WJC through drain No. 2 to fulfill the raw water demand for drinking water supply in Delhi. The water segment is terminated into Wazirabad reservoir formed due to stagnation of water at Wazirabad barrage. The reservoir water is pumped to the various water works as raw water for treatment to meet drinking water demand of the capital city. No or very little water is allowed to flow downstream Wazirabad barrage during lean seasons.

The third segment having length of 22 kms is located between Wazirabad barrage and Okhla barrage. This segment receives water from seventeen sewage drains of Delhi and also from WJC and Upper Ganga Canal via Najafgarh drain and Hindon cut canal respectively. Little contribution of water is also made in this segment by Surghat, where Ganga and Yamuna water is provided for bathing purposes. This river segment terminates into Agra Canal, which is used to augment its flow for irrigation in the states of Haryana and Uttar Pradesh.

The fourth segment having a length of 973 km initiate immediately downstream to Okhla barrage and extends upto confluence to Ganga River at Allahabad. The source of water in this segment are ground water accrual, its tributaries like Hindon, Chambal, Sindh, Ken, Betwa etc. and waste water carrying drains of Delhi, Mathura-Vrindavan, Agra and Etawah. The water of this segment is used for drinking and industrial uses at Mathura & Agra.

In the Himalayan stretch, the Yamuna River has a steep fall with an average of 19.1 metre/km. In plain stretch the river flattened gradually with an average of 0.2 metre/km. The rate of fall in various stretches of river is presented in Table 2. As reflected from Table 2 there is remarkable difference in rate of fall in valley profile of the Himalaya and Plain stretch. The maximum rate of fall i.e. 59 metres per km is in the first 25 km of river from its origin, while it is minimum (0.08 metres per km) in the 768 km long tail end starting from Agra.

Table 2: Rate of fall in Yamuna River Stretches

S.No	Stretch	Length of Stretch (km)	Rate of Fall (m/km)
1	Upper Himalaya Stretch	25	59
2	Himalaya Stretch	152	19.1
3	Total Plain Stretch	1224	0.2
4	Lower Plain Stretch	768	0.08

The ground elevation in the Yamuna River basin varies from about 6320 meters above mean sea level (MSL) near Yamnotri Glacier to around 100 m above MSL near the confluence of Yamuna River with River Ganga at Allahabad. The topography of the Yamuna basin can be classified into three groups i.e. Hilly Region – more than 600 m above MSL; Foot hills and Plateau region – 300 m to 600 m; Plains and valleys 100 m to 300 m above MSL. On the basis of this topographic classification 11700 km^2 basin area (about 3.19%) can be classified as hilly, while remaining equally divided between plains and plateau regions with 161,231 km^2 & 172,917 km^2 respectively.

Analysis of Aquifer System in Active Flood Plain Areas of Ganga and Yamuna River Basin

Analysis of Shallow Aquifer System in Ganga Basin from Gangotri to Sangam at Allahabad

The cities selected for carrying out this study have been assigned number for preparation of curves i.e in case of Ganga basin Haridwar (1), Muzaffarnagar (2), Kanpur (3), Moradabad (4), Ghaziabad (5), Allahabad (6) and Dehradun (7) and in case of Yamuna basin starting from Dehradun (7), Yamunanagar (8), Panipat (9), Sonipat (10), Faridabad (11), Karnal (12) and Allahabad (6). The locations are shown in fig. 1 below:

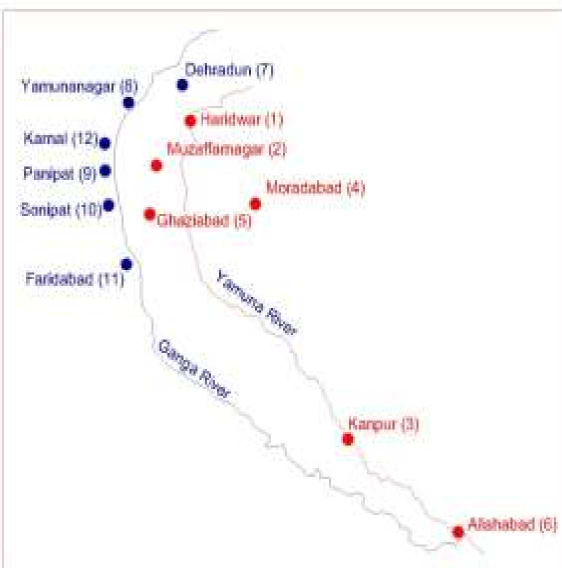


Fig. 1, Location of Cities along Ganga and Yamuna rivers in India

The location numbers mentioned in fig.1 above are same as those on the curves in the Comparative Study of Surface and Groundwater Quality between Active Flood Plain Areas of Ganga River basin from Gangotri to Sangam at Allahabad and Yamuna River Basin from Yamnotri to Sangam at Allahabad section.

Haridwar

Alluvium is the main water bearing formation in the area, which consists of coarse sand, fine sand and silt. Ground water in Hardwar district occurs under unconfined, confined and semi-confined conditions. The aquifers are separated with thick clay with considerable thickness, which act as confining layers. The water level data suggests the presence of multilayer aquifer system. The first one is unconfined and the others are semi-confined to confined. The depth of first unconfined aquifer ranges from 4 to 8 m bgl and the others are 18 to 25 m bgl, 40 to 60 m bgl and 90 to 120 m bgl. Due to variable thickness of clay layers, the aquifers become double layered from west to east.

Muzaffarnagar

The entire Muzaffar Nagar district underlains by the quaternary alluvium deposited by Ganga and Yamuna river system. Lithologically the alluvial sediments comprise of sand, silt, clay and kankars in varying proportions. The perusal of all available lithological logs of the tubewells in the area reveal the complex configuration of alluvial sediments showing quick alteration from finer to coarser lithology. By and large the four distinct groups of permeable layers occurs in the area down to 450.00 mbgl. The top sandy clay bed 3-75 m in thickness covers the entire district. After top clayey layer first aquifer starts and with varying thickness at different places continues down to 185 mbgl. Lithologically the aquifer comprises mostly medium to coarse sand but gravels and kankars are also encountered sometimes. This aquifer at places, can be sub divided into two sub groups due to the presence of either clay lenses or sub regional clay layers.

The second aquifer occurring at varying depths between 115 and 235 mbgl is separated by 10-15 m thick clay layer from the first upper aquifer. The second group of aquifer consists of less coarse sediments than that of first one and at places kankar and clay lenses also occur.

The third aquifer is separated by second aquifer by thick clay layer. The fine textural third aquifer ranges in thickness between the depths 255 to 329 mbgl. The third aquifer is followed by a clay layer. The thickness of the fourth aquifer varies between the depths 355-488 mbgl.

The aquifer material becomes coarser from west to east. The top clay layer is thickest at Lakkheri, Rajpur and Budhana in the south western part of the district but is almost absent at Sukratal in the eastern most part of the district. In general it can be observed that the river Ganga has deposited coarser material compared to those deposited by river Yamuna.

Kanpur

The Kanpur Nagar District is part of Indo Gangetic Plain. The silt, gravel, and sands of different grades are main water bearing formations. The ground water occurs under unconfined condition in phreatic zones and under confined condition in deeper zones. The sedimentological constitution of the subsurface granular zones shows remarkable variation in the depth and the nature of occurrence in north and southern part of the district. In southern part specially along Yamuna river, feldspar-quartz, Jaspar sands and gravel (Mourum) are the main constituents of the granular zones that occurs comparatively at shallow levels i.e. 24 to 57 mbgl whereas in the northern parts along the Ganga river, these reworked sedimentary formations are existing at deeper levels i.e. 265 to 310 mbgl. The provenance of these sedimentary formations is mainly

Bundelkhand Granite Complex of Archean age and Vindhyan Sandstone of Puranas. In the northern part the silt and clay sediments forming thin lensoid beds are frequently occurring in depth.

In the district shallow aquifer in the depth range of 20-96 mbgl have been tapped or utilized through cavity and stainer wells. The specific yield of unconfined aquifer is 12%. The deep drilling down to basement by CGWB has revealed the existence of potential granular zones in the depth range of 250-450 mbgl. The transmissivity of deeper aquifer varies between 1705 to 6000 m^2/day.

Moradabad

The district is underlain by alluvial sediments having thickness of around 1000m (ONCG) comprising clay, silt and various grades of sand. Limited drilling carried out for ground water exploration down to a depth of 450 mbgl reveals the presence of potential aquifers with a marked change in sedimentation below 390mbgl. The sediments down to 390 m can be boradly divided into two aquifer groups. The upper aquifer group down to 180 m being exploited extensively by state & private tubewells. The second potential aquifer group present below 180 m depth, still remains to be fully harnessed for optimum utilization. For proper management of ground water resources, it is recommended to tap this aquifer in future. Deep drilling below 400 m is the need of the area for proper understanding of deeper aquifers.

The cumulative thickness of screened granular zones in these aquifer groups varies from 36 to 112 m. The average yield varies from 1445 to 5220 lpm for drawdown ranging from 1.85 m to 8.7 m. The specific capacity of tubewells varies from 222 to 1263 lit/min/m of drawdown.

Ghaziabad

On the basis of exploratory drilling carried out in the area three tier aquifer system has been identified down to a depth of 450 mbgl. The first aquifer system extends down to a depth of 125 mbgl and extends down to 200 mbgl in north part of the district. Thickness of aquifer decreases in the western part of the district and depth of bedrock is shallow. The aquifer material is medium to coarse grained sand exception being trans Hindon area. The yield varies between 1000 and 2500 lpm. Transmissivity ranges from 300-2000 m^2/day. The quality of formation water is good in the eastern part of the district and deteriorates in the western part of the district in trans Hindon area. Second aquifer system exists in the depth ranges of 170-350 mbgl. The aquifer is medium to fine grained sand with occasional coarse grained sand. The quality of formation water is good. The tubewells are yielding 1000-2000 lpm at a considerably high drawdown. The third aquifer system occurs below 350m and continues down to depth explored of 450 m. Since no tubewell has been constructed in this aquifer group, therefore aquifer parameters are not known. As per electrical log the quality of formation water seems to be good.

Ground water occurs in the pore spaces of this unconsolidated sediments in this zone of saturation. The ground water generally occurs under unconfined conditions and depth to water level ranges between 1.70 to 24.60 mbgl during pre-monsoon period (May 2005) and during post monsoon period (Nov. 2005) if varies between 2.20 to 23.37 mbgl where as piezometric head of deeper aquifers rests between 3.04 to 16.37 mbgl. The general slope of water table is from north to south and broadly follows the direction of surface slope. The hydraulic gradient varying from 0.4 to 4.8 m/Km. The maximum water level fluctuation (4.83) was observed in Rajapur (Pz) of Rajapur block. The water level elevation varies from 192 mamsl to 214 mamsl. The long-term water level trend in 10 years (1998 to 2007) is observed 0.2125 m/year during monsoon and 0.3016 m/year during post monsoon period.

Allahabad

Allahabad district covers an area of 5246 sq.km and falls in the in Doab of famous Ganga and Yamuna river. Thickness of alluvium encountered in Trans-Ganga area is upto 350.m while it is very less in Trans Yamuna area i.e. maximum up to 75.00m.

Exploratory drilling data of the district reveals that there are three tier aquifer system in Trans Ganga area while fractures are encountered in Trans Yamuna area. Yield of tubewells in alluvial area varies from 1000-3000 lpm with 6.00m drawdown. Potential Zones are encountered in Central as well as younger alluvium in the district.

Water table elevation contour map the groundwater flow is towards river Ganga and Yamuna (limited portion) Level of G.W. draft is 69.12% and all blocks of the district is under "SAFE" category. Maximum ground water development is 89.48% and minimum in Koraon block (32.62%). Ground water quality in general is fresh and potable except few pockets. Deeper aquifer also reveals that there is no contamination or pollution of groundwater.

Analysis of Deep Aquifer System in Ganga Basin from Gangotri to Sangam at Allahabad

Yamunanagar

The ground water exploration in the district reveals that clay group of formations dominates over the sand group in the district area. Ground water in the district occurs in the alluvium under water table and semi-confined to confined conditions. These aquifers consist of sand, silt, gravels and kankar associated with clay and form highly potential aquifers. In alluvium, the permeable granular zones comprise fine to medium grained sand and occasionally coarse sand and gravel. Their lateral and as well as vertical extent is extensive. In Kandi belt, which has not been explored fully boulders cobbles and pebbles, constitutes the major aquifer horizon. Siwalik Hills occupy marginal areas in the northeastern parts of the district constitute a low potential zone.

In Kandi areas, the shallow aquifers are isolated lenses embedded in clay beds whereas aquifers in alluvial areas occur on regional scale and have pinching and swelling disposition and are quite extensive in nature. These aquifers generally consists sands (fine to coarse grained) and gravels and are often intercepted by clay and kankar horizons. These aquifers are under unconfined to semi-confined conditions and support a large number of shallow tubewells within the depth of 50m only. The discharge of these tubewells varies between 100lpm and 500 lpm for moderate tubewells.

Karnal

The area falls in the Upper Jamuna Basin and the principal ground water reservoir in the area is unconsolidated alluvial deposits of Quaternary age. Groundwater in near surface zone occurs under water table conditions and occurs under semi confined to confined conditions in deeper aquifers. Rain fall and seepage from the river Yamuna, canal networks and irrigation is the principal source of ground water recharge in the area.

The study of exploratory boreholes drilled in the district during the Upper Jamuna Project of Central Ground Water Board indicated presence of three aquifer groups upto 450m depth below ground level.

Aquifer Group-I: The aquifer group I is composed of different sand and clay lenses and extends from surface downwards to different depth varying down to 90m to 180m at different places and occurs all over the area. This is composed of relatively coarser sediments. This group of aquifers is underlain by a clayey horizon 10-15m thick which is regionally extensive. The average transmissivity of this group was calculated by the Upper Jamuna Project of CGWB to be of the order of 2200 m^2/day, lateral permeability of the order of 24m/day and average storativity as 0.12.

Aquifer Group-II: This group is composed of different sand and clay lenses and lies below aquifer group-I and occurs at varying depths ranging between 115m and 195 m to 215m and 285m. The sediments of this group are less coarse and are mixed with some kankar. This group is underlain by another clayey horizon, which is considerable thick at places and appears to be regionally extensive. The average transmissivity of this group is 700m^2/day, the average lateral permeability is 7.2m/day and the average storativity is $1x10^{-3}$.

Aquifer Group-III: The aquifer group III is composed of thin sand layers alternating with thicker clay layers and occurs at variable depths ranging between 314 m to 405m.bgl. The granular material of this group is generally finer and more so in the southerly direction. This group has an average transmissivity value of 525 m^2/day, and average lateral permeability and average storativity values of the order of 7.1m/day and $4.5x10^{-4}$ respectively.

At shallow depths the aquifer are under unconfined conditions whereas at deeper levels these are under semi confined or confined conditions. Under exploratory drilling programme Central Ground Water Board has constructed 9 deep tubewells in the district. The depth of these tubewells are in the ranges of 202m to 316m. The discharge of these wells ranges from 825 to 4542 lpm for draw down varying from 4 - 20m.Depth to water level in the district ranges between 3.96m bgl to 22.54 m bgl. In the pre monsoon period.

Panipat

The district forms a part of Indo gangetic plain and lies in Yamuna Sub basin of main Ganga basin. Physiographically, the district is characterized by two distinct features i.e. vast upland plain and Yamuna flood plain. The width of the flood plain varies according to the amount of shift experienced by the river. It is narrow in the Northern part and widens downstream. The district is mainly drained by the river Yamuna and its tributaries.

The district is occupied by geological formations of Quaternary age comprising of Recent alluvial deposits belonging to the vast Gangetic alluvial plains. The Central Ground Water Board has drilled four exploratory boreholes in the depth range of 103 to 460 m and 25 piezometers in the depth range of 33 to 348 m to delineate and determine potential aquifer zones, evaluation of aquifer characteristics, behavior of water levels etc. The ground water exploration undertaken by CGWB has revealed the existence of 8 – 23 granular zones down to a maximum depth of 460 m. These zones mainly comprise of various grades of sand and gravel. The first granular zone forms the water table aquifer and occurs down to 50 - 150 m below ground level. The second aquifer occurs between 130 and 250 m depth, the third one exists between 286 and 366 m depth. Total thickness of the alluvium is not precisely known. However, the bedrock has not been encountered up to 460 m depth at village Dadlana (deepest exploratory borehole) in the district. The discharges range from 605 to 3258 lpm for 6 – 20 m of draw down. The transmissivity of the aquifers lies between 350 and 1990 m^2 / day.

Sonipat

Ground water occurs in alluvial sand, silt, kankar and gravel, which form potential aquifer zones. Depth to water level during pre-monsoon varies from 1.41 – 23.22m while during post-monsoon it varies from 0.99 – 24.46m. The depth to water level lies within 10m below the land surface in most parts of the district. It rests between 2 to 25m deep in the eastern side and 2 to 10m in the north western parts of the district. Only in small patches in the Rai block, water table is deeper having range of 20m to 40m. Water table elevations range from 230 to 220m amsl and the general ground water flow is from northwest to southeast. In general, the water table has declined all over the district over the past decade. During past few decade the district has recorded a fall of less than 1m to 7m .The decline was 2 to 4m in most parts of the district. Long term water level fluctuations indicate rise of water level over a period of last one decade in Mundlana, Kathura, Kharkhoda and Rari blocks. The trend of rise of water level is in the range of 0.05 to 0.32m/year.

The trend of decline of water level is 0.05 to 0.95m/year. Central Ground Water Board has drilled 15 wells under ground water exploration programme; 8 are exploratory wells, 5 are piezometers and 2 are slim holes. Out of 8 boreholes drilled for ground water exploration, 7 were abandoned due to poor quality of ground water or due to inadequate thickness of permeable granular zones. Granular zones exist down to 460m depth i.e. to depth explored.

However, the chemical quality of ground water is not fresh in deeper horizons in most parts of the district and in shallow horizons; in some parts. In general, the quality of ground water in shallow dugwell zones is fresh in the eastern and north, northwest parts and gradually gets deteriorated in the western and southwestern parts. Also the deep zones below 150m depth contain brackish / saline ground water. A number of shallow tubewells exist in all the blocks – more in number in Sonipat, Rai and Ganaur block and these tap water bearing zones in the shallow unconfined aquifer group. These tubewells yielded 300 to 600 lpm for moderate drawdowns. Detailed test drilling has established occurrence of three distinct aquifer groups, down to

450m depth in Upper Yamuna Basin which includes Sonipat district.

Aquifer group-I which was in unconfined state extends from water table down to 70m depth. A tubewell located at Khera in the eastern part of the district and tapping this aquifer group-I, yielded 4540 lpm for about 7.5m of drawdown. Aquifer characteristics at Khera site were – transmissivity: $2340m^2$/day, lateral hydraulic conductivity – 36m/day and specific yield – 2.15 x 10-1 (21.4%). This aquifer group-I contains fresh water in eastern parts of the district.

Aquifer group-II which is under semi-confined/confined state occurs in the depth range of 90 to 200m and has not been tested for its yield and aquifer characteristics since the formation water is saline. Aquifer group-III which too is under confined state occurs in the depth range of 250 to 400m and contains brackish saline ground water.

Faridabad

Ground water occurs in alluvium and the underlying weathered/ fractured quartzites. Alluvium comprises sands silt , Kankar and gravel which form the principal ground water bearing horizon. In Quartzite formation, occupying the north-western part of the district, ground water occurs in weathered and jointed fractured horizons. Weathering and fracturing has resulted in formation of semi-consolidated sand beds (BADARPUR SANDS) which form potential aquifer zones. This quartzite format ion has not been explored for ground water occurrence.

In alluvium, granular zones are evenly distributed in entire thickness which is negligible near the quartzite outcrops to over 350 m in the eastern parts near Yamuna River.

The ground water exploration in Faridabad district has been undertaken at large number of locations by the Central Groundwater Board. Out of these, 38 exploratory wells one slim hole and 19 piezometers were constructed in the district. 12 exploratory wells were abandoned due to poor quality of ground water and lack of promising aquifers. In general, 6-14 granular zones mainly comprise fine sand, silt , clay and kankar. The discharge of successful exploratory wells varies between 200 and 6629 lpm with draw down of 2.39-9.12 m. To assess the aquifer parameters, aquifer performance tests were conducted. The transmissivity values in the area vary between 125 and $1645m^2$/day.

Analysis of Deep Aquifer System in Yamuna Basin from Yamnotri to Sangam at Allahabad

Dehradun

Several water samples were collected from different groundwater structures located in District Dehradun, during Pre-monsoon, 2007. The samples were got analyzed for their electrical conductivity (EC), pH, calcium, magnesium, carbonate and bicarbonate. The groundwater is suitable for domestic and irrigation purposes, in respect of these parameters.

The EC, in District Dehradun, ranges between 80 and 659 micro mhos/cm at 250C. The higher values are there around the Dehradun and Doiwala townships.

Haridwar

The partial chemical analyses of samples of the district reveal that the chemical parameters of ground water are well within permissible limit and suitable for drinking and irrigation purposes.

Muzaffarnagar

Ground water in phreatic aquifer in general, is colourless, odourless and slightly alkaline in nature. The specific electrical conductance of ground water in phreatic zone ranges from 224 – 1885 µs/cm at 25˚C. Fluoride ranges from 0 – 0.79 mg/l, which is within permissible limit.

It is observed that the ground water is suitable for drinking and domestic uses in respect of all the constituents. Nitrate is found in excess of permissible limit 15 (>45mg/l) in few samples analyzed, which is likely due to return irrigation flow from agricultural fields and often improper waste disposal. Phosphate is not found in ground water. The Arsenic content is within limit of permissibility of BIS.

Kanpur

The ground water of Kanpur Nagar district is colourless, odourless and slightly alkaline in nature. The Electrical conductance ranges from 470-1560 µ/cm at 25˚C. The Fluoride is within the permissible range from 0.47-0.96 mg/l. Phosphate is found nil in the area. It is observed that quality of water is good for drinking, domestic and all other purposes. The arsenic content has been found ranging from Nd to 42mg/l. The trace metals Zn, Mn, Ni, Pb are within the permissible limit except for copper 1249mg/l and iron 6.236 mg/l at Kanpur.

Moradabad

Ground water in phreatic aquifers in general is colourless, odourless and slightly alkaline in nature. The specific electrical conductance of ground water in the phreatic zone ranges from 300-1080 micro siemens/cm at 25˚C. The conductance below 750 micro siemens/cm at 25˚C have been observed in 67% of the samples analysed. It is observed that ground water is suitable for drinking and domestic purpose in respect to constituents except nitrate. Nitrate is found in excess 45 mg/l in about 33% of sampels analysed which is due to the use of fertilizers for agriculture and other untreated waste disposal. Phosphate is not found in ground water. The As (Arsenic) has been found ranging from nd to 70 micro gm/litre in Moradabad block (Ashiyana 70 microgram/litre).

Ghaziabad

Ground water in phreatic aquifers, in general, is colourless, odourless and slightly alkaline in nature. The specific electrical conductance of ground water in phreatic zone ranges from 527 to 3318 µs/cm at 25˚C. Conductance below 750 µs/cm at 25˚C has been observed in a 44% of the analysed samples, whereas, above 2250 µs/cm at 25˚C in 11% of the samples. It is observed that the ground water is suitable for drinking and domestic uses in respect to all constituents except for total Hardness & Nitrate. High concentration (>600 mg/l), total hardness in found in 11% of the samples with a maximum value of 990 mg/l from Bhojpura. Nitrate is found in excess of permissible limit (>45 mg/l) in 22% of the samples analysed with a maximum of 168 mg/l from

Bhojpura. High nitrate values may be due to return irrigation flow from agricultural fields where indiscriminate use of fertilizer is being done. The Arsenic content has not been detected in the ground water of the district.

Allahabad

The chemical analysis of shallow ground water consists of pH, E.C., Na, K, Ca, Mg, HCO3, CL, SO4, NO3, F and TH as CaCO3 reflects that there is no contamination of the shallow ground water in the district and all the constituents are well within the range. The chemical data of shallow aquifers reveals that the groundwater quality is more deteriorated in canal command area E.C. varies from 200-2O80µ siemens/cm at 25°C. It is interesting to find that different radicals in the shallow ground water have not changed over the year's in spite of upcoming canal irrigation and use of fertilizers.

Data of water samples from deeper aquifers are few but there analysis reveals that the water is safe and potable. It is observed that the E.C. and other salts are in higher concentration in alluvial area than hard rock area. The quality in hard rock area is inferior near the stream than away from the stream.

Analysis of variation in water quality from the upland areas of Yamnotri to its confluence at Sangam Allahabad

Dehradun

Several water samples were collected from different groundwater structures located in District Dehradun, during Pre-monsoon, 2007. The samples were analyzed for their electrical conductivity (EC), pH, calcium, magnesium, carbonate and bicarbonate. The groundwater is suitable for domestic and irrigation purposes, in respect of these parameters.

The EC, in District Dehradun, ranges between 80 and 659 micro mhos/cm at 25˚C, for most part of the district the EC is around 200 micromhos/cm. The higher values are there around the Dehradun and Doiwala townships.

Yamunanagar

Central Ground Water Board has carried out studies for chemical quality of groundwater. The range of chemical constituents (anion and cation) along with pH and EC analysis of water samples from shallow aquifers reveals that ground water is alkaline in nature and moderately saline at few places. All chemical parameters are within the permissible limits for safe drinking waters set by BIS except nitrate and arsenic at a few locations. Among anions, bicarbonate is the dominant anion and among cations, none of the cation dominates. By and large, quality of ground water is suitable for drinking purposes.

Karnal

Data of chemical analysis of water samples from shallow aquifers indicates that ground water is alkaline in nature and is moderately saline. All chemical parameters are well within the permissible limits for safe drinking waters set by Bureau of Indian Standards (BIS) except fluoride and arsenic at a few locations. Among anions, bicarbonate is the dominant ion and among cations none of the cations dominate. By and large, quality of ground water is suitable for drinking purposes.

Panipat

The shallow ground water of the district is alkaline in nature and is of low to medium salinity. The data on chemical quality of water from shallow (Phreatic) aquifers indicates that all the chemical parameters i.e. major cations (Ca, Mg, Na& K) and major anions (CO_3, HCO_3, Cl & SO_4) are well within the permissible limits set by the BIS, 1991 in most areas but higher concentrations occur at some places. Among the anions, bicarbonate is dominant, and magnesium and sodium are the dominant cations. Marginal quality water is found in the south western parts of the district. High fluoride is found in large parts of the district more than 60%. High nitrate concentration is found in patches in Madlauda block. Ground water is found suitable for irrigation in general. However, for drinking some constituents are high and fluoride problem is prevalent in large parts. High concentration of heavy metals like Copper and Iron have been found.

Sonipat

The shallow ground water of the district is generally alkaline in nature and is moderate to highly mineralized with EC ranging from 597 to 6710µS/cm. at 25˚C.

Ground water occurring in the southern and N-W parts of the district is more saline as compared to ground water occurring in the rest of the district. Among anions, either bicarbonate predominates or none of the anion dominates. Similarly, among cations, sodium predominates in 50% of the samples and in the remaining calcium + magnesium combined dominates.

On comparing the ionic concentration of major ions with the recommended limits prescribed by Bureau of Indian standards for drinking waters, it is found that more than half (68%) the ground waters are not suitable for drinking purposes mainly due to salinity and fluoride contents that exceed the maximum permissible limits of these chemical parameters, which are 3000µS/cm. and 1.5mg/l respectively.

Plot of USSL diagram used for the determination of irrigation rating of ground waters indicates that ground waters at several places fall under C2S1, C3S1, C3S2, C4S2 classes of irrigation rating. These waters are, therefore, suitable for customary irrigation for salt tolerant crops like wheat, rice, maize, gram e4rdtc without any fear of salinity hazards to the crops. Waters falling under C4S3 and C4S4 classes are likely to cause salinity as well as sodium hazards. It would be better if such waters are used for irrigating salt tolerant crops along with appropriate amount of gypsum on well drained soils.

Faridabad

The shallow ground water of the district is alkaline in nature (pH 7.75 to 8.62) and is moderately to highly saline (EC 693 to 3590qS/cm). Among anions, bicarbonate predominates at some places, whereas at other places either none of the anion dominates or chloride is dominant. Among cations, by and large, sodium is the dominant cation. At some places mixed cationic character has been observed. Comparing the concentration values of major ions with the recommended desirable and permissible concentrate- ion limits for drinking waters (Bureau of Indian Standards). It is found that more than half (75%) of the ground waters are not suitable for drinking purposes mainly due to fluoride content that exceeds the maximum permissible limit of 1.5mg/1.

Analysis of Shallow and Deep Aquifer Water Quality in Ganga Basin from Gangotri to Sangam at Allahabad

The analysis of water quality is based on the secondary sources from Central Groundwater Board as well as State Groundwater Board and primary data was also generated in order to ascertain the groundwater quality in shallow and deep aquifer from shallow farmer wells ranging from 50 m to 90 m and the deep aquifers from deep tubewells of UP Jal Nigam as well as exploratory tubewells of Central Groundwater Board varying from 90 m to 320 m.

The interpretation of data was done for physical, chemical and bio-logical parameters in conformity with IS:10500. It was found that the upper Ganga basin in shallow aquifer system has got variation from alkaline condition to acidic condition especially during the recharging season i.e at the time of rainfall, snow-melt and western disturbances, however the deeper aquifers have got moderately hard and alkaline water condition throughout the year.

Analysis of Shallow and Deep Aquifer System in Yamuna Basin from Yamnotri to Sangam at Allahabad

The analysis of water quality is based on the secondary sources from Central Groundwater Board as well as State Groundwater Board and primary data was also generated in order to ascertain the groundwater quality in shallow and deep aquifer from shallow farmer wells ranging from 30 m to 50 m and the deep aquifers from deep tubewells of UP Jal Nigam as well as exploratory tubewells of Central Groundwater Board varying from 50 m to 123 m.

The interpretation of data was done for physical, chemical and bio-logical parameters in conformity with IS:10500. It was found that the upper Yamuna basin in shallow aquifer system is moderately alkaline and remains so throughout the year.

Comparative Study of Surface and Groundwater Water Quality between Active Flood Plain Areas of Ganga River basin from Gangotri to Sangam at Allahabad and Yamuna River Basin from Yamnotri to Sangam at Allahabad

The active flood plain of Ganga river basin is limited in its aerial extent in the upper Yamuna basin area, especially in the Gangotri region, because of the hard rock formation, however there is a drastic expansion in active floodplain areas at the time of emergence of Ganga river in the plain areas i.e Moradabad, Kanpur, Allahabad etc.

The surface water quality of Ganga river basin is fit for drinking and domestic purpose in its upper reaches, however contamination in small portion when the Ganga river enters cities like Kanpur and Allahabad where it is affected due to rapid urbanization, however the contamination will further increase with the pace of development of urbanization through tourism etc especially in its upper reaches.

In contrast to the surface water the groundwater condition and behavior of Ganga basin is better because of the presence of Sivalik Group of rocks which is highly permeable due to boulders and coarse sand followed by the Vindhyan system overlain by thick alluvium mainly consist of coarser sand, gravel etc.

The active flood plain of Yamuna basin is mainly found in the areas like district Karnal, Panipat and Sonipat, and these flood plains decreases in its dimension in the lower region due to construction of dams, barrages, flow regulators etc.

The Yamuna basin on the other hand has got good water quality in its upper reaches, especially in Yamnotri upto Dehradun areas, however the quality of Yamuna as soon as it enters Delhi becomes highly polluted and is not fit for any use without proper treatment upto tertiary level.

The groundwater in Yamuna river basin is moderately hard and alkaline upto shallow depth and at places it is fit for drinking upto Panipat areas, however in the deeper aquifers, the groundwater is highly saline and alkaline in reaction because of the chemical leaching due to the presence of Aravali rocks which are weathered quartzite.

Pre-monsoon Depth to Water Level in Ganga & Yamuna Basin

The pre-monsoon depth to water level for the Ganga and Yamuna basin area is shown in fig. 2 below, the variation in pre-monsoon water level in Ganga and Yamuna basin indicates that the Yamuna basin doesn't have shallow water level whereas the Ganga basin has got shallow water level which clearly indicates that the response of the recharge is much better in Ganga basin and so the aquifer system is better in Ganga Basin

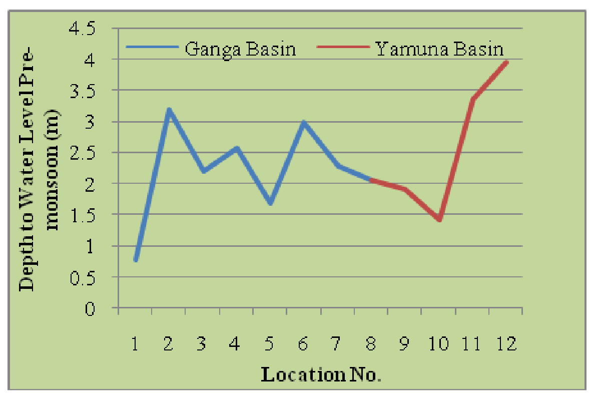


Fig. 2: Pre-monsoon Depth to Water Level in Ganga & Yamuna Basin

Post-monsoon Depth to Water Level in Ganga & Yamuna Basin

The post-monsoon depth to water level for the Ganga and Yamuna basin area is shown in fig. 3 below. It indicates that the Yamuna basin doesn't have shallow water level whereas the Ganga basin has got shallow water level which clearly indicates that the response of the recharge is much better in Ganga basin and so the aquifer system is better in Ganga Basin.

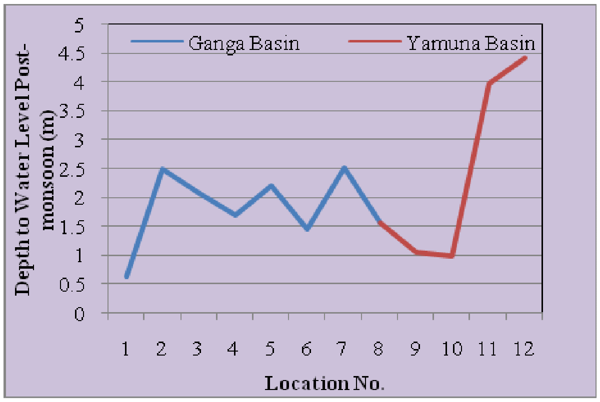


Fig. 3: Post-monsoon Depth to Water Level in Ganga & Yamuna Basin

Water Level Fluctuation in Ganga & Yamuna Basin

The water level fluctuation for the Ganga and Yamuna basin area is shown in fig. 4 below. It indicates that the fluctuation range is much higher in Ganga Basin whereas it is very less in Yamuna basin which further confirms that the aquifer system in Ganga basin is better and so is the Groundwater resource potential.

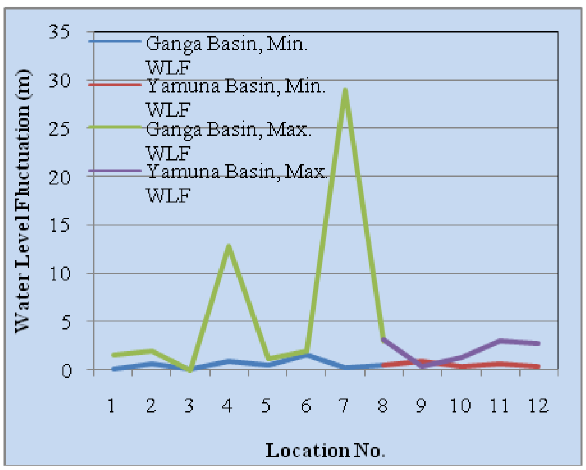


Fig. 4: Water Level Fluctuation in Ganga & Yamuna Basin

Temperature Variation in Ganga & Yamuna Basin

The temperature variation for the Ganga and Yamuna basin area is shown in fig. 5 below. The variation is recorded higher in Ganga basin than the Yamuna basin which clearly indicates the Physiographic features are undulatory in Ganga basin than the Yamuna basin. The Ganga basin has got comparatively higher altitude and the response of snowfall and climate change. With due respect of global warming.

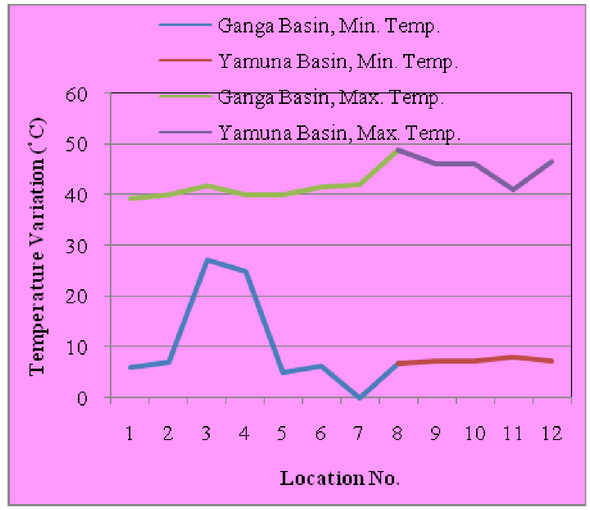


Fig. 5: Temperature Variation in Ganga & Yamuna Basin

Rainfall & pH variation in Ganga & Yamuna Basin

The rainfall and pH variation for the Ganga and Yamuna basin area is shown in fig. 6 below. The pH variation has got a direct response in Yamuna and Ganga basin which reciprocates to the rainfall, which means that higher the rainfall makes pH almost neutral to acidic in nature in Ganga basin whereas in Yamuna basin it is not much clear specially in lower Yamuna basin from Delhi to Allahabad, which clearly indicates that the impact of wastewater is more in Yamuna basin than Ganga basin and also the snowmelt has got more response in Ganga basin.

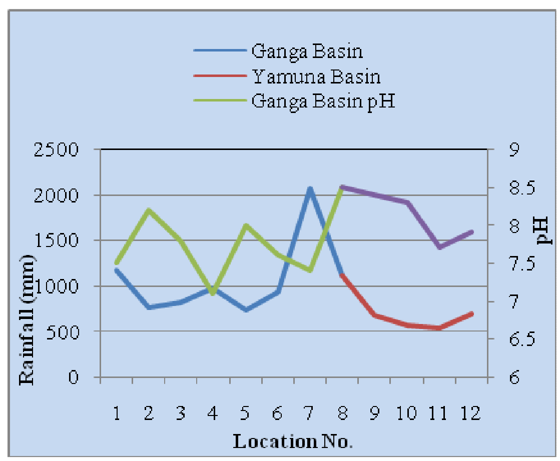


Fig. 6: Rainfall & pH variation in Ganga & Yamuna Basin

V. CONCLUSION & RECOMMENDATIONS

It is thus concluded from the above discussion that the Ganga basin has got the good hydro-geological and hydrological system and the local geology is found positive in nature which does not really react with rainwater as a result the groundwater quality remains good throughout the year except at few patches in its upper region where there is fluctuation from acidic to alkaline condition in the shallow aquifers. However the deeper aquifers are found to be moderately hard and alkaline in reaction throughout the year.

It is also found that there has not been much storage capacity created in the stretch of Ganga basin from Yamnotri to Allahabad by virtue of which the surface water always is found to be in running condition and maintain good quality due to regular flushing and aeration.

It is recommended therefore that in the Ganga basin the inter-mixing of shallow and deep aquifer water should be done in order to maintain the groundwater quality which will be almost neutral in reaction and will be fit for drinking and domestic purposes.

The storage capacities should not be encouraged rather the rainwater should be properly guided by virtue of watershed management in order to maintain and improve the surface water quality by providing proper runoff.

The local patches in Moradabad, Kanpur and Allahabad or wherever found contaminated should be treated properly by virtue of providing treatment plants on the nallas and drains falling in the Ganga river areas.

The Yamuna river basin has got very complex hydro-geological and hydrological system by virtue of which the Yamuna river becomes meandering in nature rather braided, by virtue of which the swamps and lakes are the natural storage feature which spoils the water quality of Yamuna river basin. Comparatively the Yamuna river basin has got limited recharge where partial snowmelt water comes which does not support the runoff of Yamuna river basin. The storage capacity in terms of dams, reservoirs and barrage etc further deteriorate the Yamuna river water discharge and quality and in fact it becomes dry in Panipat and Sonipat areas, however the Yamuna river water in Delhi has got a good amount of sewage and industrial waste water in the tone of 750 MGD by virtue of which the Yamuna becomes the sewage carrier river down below the Delhi areas until Chambal river, which dilutes the Yamuna river water quality.

The groundwater quality in the shallow aquifers of Yamuna river basin is moderately hard and alkaline in reaction but in the areas like Delhi and further in downstream direction becomes contaminated. The areas from Sonipat to Agra in a stretch of 300-400 km has got really bad shape because the shallow aquifers are contaminated due to urbanization and industrial impact and deeper aquifers are saline in reaction.

It is recommended further that this stretch of Yamuna belt should be taken care properly with utmost urgency and proper treatment devices on the drains and nallah joining Yamuna should be provided on the drains joining Yamuna. For salinity removal it is recommended that for drinking purpose the reverse osmosis system maybe used and the reject water should be given to the salt resistant plants in the green belt areas. However, the attempt should be made for rainwater harvesting and groundwater recharging through proper watershed management. The emphasis should be given on the design of watershed, with the pace of urbanization. The rainwater harvesting system should also be designed for dilution of salinity in the deeper aquifers.

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ISSN 2250-3153

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